A CONTINUOUS FLOW BULK BOX DUMPER

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
Alfonso Diaz-Duran
1963

This is to certify that the

thesis entitled

A Continuous Flow Bulk Box Dumper

presented by

Alfonso Diaz

has been accepted towards fulfillment of the requirements for

M. S. degree in Agricultural Engineering

B A Stout

Major professor

Date 22 April 63

O-169

A CONTINUOUS FLOW BULK BOX DUMPER

By

Alfonso Diaz-Duran

AN ABSTRACT OF A THESIS

Submitted to the Colleges of Agriculture and Engineering
of Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE
in
AGRICULTURAL ENGINEERING

Department of Agricultural Engineering

1963

Approval B A Stout

ABSTRACT

A CONTINUOUS FLOW BULK BOX DUMPER

by Alfonso Diaz-Duran

Several universities and manufacturers have constructed experimental harvesters capable of picking tomatoes in a once-over operation.

Many studies have been conducted to investigate the use of bulk boxes in handling mechanically harvested tomatoes for processing. A bulk box dumper mechanism was found necessary to complete the mechanization of the harvesting and handling of processing tomatoes.

Two general types of dumping systems are a water flotation unloader and a mechanical box dumper. The water flotation unloader would not be suitable for tomatoes because some ripe tomatoes have a specific gravity greater than one and will not float. The dry mechanical dumper would damage the tomatoes when unloading.

A dumper system was designed and constructed that provided a continuous flow of bulk boxes into a water dumping tank. The boxes were partially submerged, inverted, and gently removed from the tank. The dumping capacity of this system was found to be over 50 tons per hour. The dumper mechanism did not produce appreciable injury to the tomatoes.

A water recirculation system was provided to transport the tomatoes from the dumping tank to the washing system. Non-uniform water flow resulted in an accumulation of tomatoes on the bottom of the dumping tank.

A CONTINUOUS FLOW BULK BOX DUMPER

By

Alfonso Diaz-Duran

A THESIS

Submitted to the Colleges of Agriculture and Engineering of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
IN
AGRICULTURAL ENGINEERING

Department of Agricultural Engineering

1963

ACKNOWLEDGMENTS

The author wishes to express his sincere thanks to Dr. B. A. Stout for his supervision and assistance during the investigation and preparation of this manuscript.

The author is also indebted to:

Dr. Arthur W. Farrall, chairman of the Agricultural Engineering Department, for granting the Graduate Research Assistantship which enabled the author to complete this work.

The U. S. Steel Corporation for providing funds and steel to construct the system.

Dr. S. K. Ries for arranging for growing the tomatoes and providing valuable counsel.

Messrs. Tom Burenga and Don Pettengill, for their assistance during the construction and testing phases of this work.

Dr. C. W. Hall and Dr. A. E. Erickson for acting as members of the examining committee.

Edda, my wife, for her devotion during the time spent in this country.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The U. S. production of tomatoes for processing was 5,318,200 tons in 1962, with a value of $150,148,000. The production of tomatoes for fresh market was 1,020,050 tons with a value of $142,729,000 (U.S.D.A., 1962).

Lug boxes or hampers have been used to handle hand harvested tomatoes. Lug boxes have usually been handled on pallets by forklifts; whereas, hampers have been handled by hand. There is much interest in the use of larger containers that could be handled entirely by mechanical devices.

Levin (1959) stated that the use of bulk boxes for handling fruits was increasing. He showed that their use saves time, labor, and money. One major problem, when using bulk boxes for soft fleshed fruit, has been that in the unloading operation the fruits were easily damaged by bruising, skin cuts, and punctures. This problem has been overcome in apple handling by the use of several systems of dumping, utilizing a water flotation unloader or a mechanical box dumper. The water flotation unloader would not be suitable for tomatoes because some ripe tomatoes have a specific gravity larger than one and will not float. The dry mechanical dumper would damage the tomatoes when unloading because the system does not provide any means to cushion the fruit.

Investigations on the development of a mechanical tomato harvester have been conducted at Michigan State University since 1958. Other universities and several machinery manufacturers have developed experimental machines capable of mechanically harvesting tomatoes. This indicated that means to unload bulk boxes filled with machine-harvested tomatoes have to be provided.

The advent of the mechanical harvester and the proposed use of bulk boxes in handling tomatoes has created the need for a mechanism to dump bulk boxes filled with tomatoes.

The objectives of this research were:

1. Design and construct a bulk box dumper for tomatoes.

2. Evaluate the dumping machine in terms of capacity and tomato quality.

REVIEW OF LITERATURE

Mechanical tomato harvesting and handling studies have been conducted at Michigan State University for several years. Stout and Ries (1960) described a mechanical tomato harvester under development since 1958. The harvester was a pull-type machine powered by the tractor power take-off. It consisted of a cutting device, elevator, separating bed, conveyor belts, and sorting platform.

Murphy (1960) reported that the experimental machine of Michigan State University was one of four mechanical tomato pickers in various stages of development across the country. Since that time several other manufacturers or growers have constructed experimental machines. All of them were based on the principle of once-over harvest.

Bulk handling and the mechanical unloading of boxes may be necessary with the tomato mechanical harvester when it is perfected. In past years, countless numbers of lugs, bushel crates, and boxes of tomatoes, weighing twenty to one hundred pounds each, have been handled manually. A single processing plant may have over a million lug boxes. Many small containers have been either palletized and handled with forklift equipment or have been replaced by larger containers (Anon., 1961).

Twigg (1961) stated that the use of 5/8-bushel baskets for picking and handling tomatoes, although commonly used in the East, tomatoes handled in such containers were subject to severe damage. Several experiments were conducted at the University of Maryland during 1959 and 1960 to investigate the possibilities of using water as a method of bulk handling tomatoes. It was found that the water handling on the Roma variety decreased the soluble solids slightly. There was no effect on pH or color. Water-handled tomatoes showed small weight changes. He concluded that for mechanical harvesting, bulk containers were needed to facilitate fast filling and handling.

Mechanically harvested tomatoes were placed in different sized bulk boxes in order to study the ease of handling and resulting fruit quality at Michigan State University. In general, it was found that the width of the box was not an important factor causing fruit injury, expressed either as cracks before washing or crushed fruit after washing. As the depth increased from 8 to 16 inches, injury increased for most varieties (Ries _et al_., 1961). Further investigations, during the 1962 harvesting season, were made to evaluate different types of bulk boxes and the resultant tomato quality. The results indicated that cracking increased as depth of box increased. As the depth increased from 12 to 24 inches the amount of crushed fruit increased (Stout _et al_., 1962).

Fruit Handling

The use of bulk boxes and the mechanization in fruit handling is coming to widespread use in the United States.

Applications of these methods in the tomato processing industry may be desirable.

Fruits, such as oranges, for processing have been handled completely by bulk methods. Cherries were handled in bulk cherry tanks in water and pallet tanks (Anon., 1961). According to Hedden et al. (1960), trials to handle concord grapes in bulk boxes were made. The grapes were picked, placed into lugs, and then transferred from the field container to the bulk box as the tractor moved along. When the box was filled, the bulk box was moved to a nearby loading area. Then the boxes were moved to the plant by truck. At the plant they were emptied into the wash tank. The quality of the bulk-handled grapes was equal to or superior to comparable lots that were handled in lugs.

Pallet box system for handling fresh oranges from the pickers to the packing line showed much promise for cost reduction and minimum mechanical injury to fruit as compared to the field-box system. Pallet boxes permitted handling fruit in unit loads and sizable reductions in cost of handling compared with the conventional field-box system (Grierson, 1962).

Levin and Gaston (1958) said that handling fruit in bulk boxes was rapidly becoming standard in most of the major apple producing areas of the United States. While industrial forklift trucks were used in handling palletized unit loads, they later proved just as useful in handling bulk boxes. In 1959 they stated that during the five preceding years the practice of handling apples in bulk boxes having a capacity of 16 to 24 bushels came into widespread use. During the 1958 season almost five million bushels of Michigan grown apples were handled in bulk boxes. More than 500 Michigan growers and all major processors had the forklift equipment necessary to handle bulk boxes. The first cost of a bulk box was less than the first cost of a pallet and the number of field crates required to hold the same amount of fruit. The monetary savings amounted to 2.73 cents per bushel of apples handled when using bulk boxes as compared to palletized field crate handling.

McBirney and Van Doren (1959) indicated that pallet bins were rapidly coming into use for harvesting apples in the Pacific Northwest and in other regions. Comparative fruit bruising and other injury studies showed that apples harvested in bins had slightly fewer injuries than those harvested in boxes. A 24 to 26 inch bin depth was recommended as a maximum if the apples were stored.

McBirney (1959) reported 160,000 bins were used in 1958 in Washington. Over five million standard boxes of Washington apples were harvested in these bins in 1958. In addition, over 400,000 bushels of other fresh fruits were harvested in bins in 1958 in the three Northwestern states and another million and a half bushels in British Columbia, Canada, just across the border. These bins were unloaded from the trucks with an orchard tractor equipped with a forklift. At the processing plants bins were handled with industrial forklift units.

The use of bins reduced cost of containers, saved labor, reduced storage space requirements, and cut transportation costs. Bulk bins for fruit harvesting and handling were replacing conventional lug boxes in California's deciduous-fruit packing industry. Bins with pallet bottoms were well adapted to conveyor line and forklift handling (O'Brien, 1960).

Box Dumper and Fruit Unloader Mechanisms

Many types of dumping mechanisms were used to unload fruits from bulk boxes. Levin and Gaston (1957) described a dumper of tip-up type. Bins were successively pushed into the tip-up section under a padded cover and turned 110 to 120 degrees. The fruits were then slowly fed onto a conveyor at the start of the packing line through a hinged door in the lower edge of the bin cover.

Herrick *et al*. (1958) and McBirney and Van Doren (1959) reported that in the bin-inverting type of dumper, the bins were fed from the supply track or conveyor. The bin was held between an upper and a lower conveyor belt. There the bin was slowly lifted off the apples which were carried on a conveyor belt. The apples were then spread to a single continuous layer by successive conveyors after which the apples entered the washer at the head of the packing line.

McBirney (1959) stated that some bins were built with a hinged or sliding door opening from the bottom of one side. These were emptied by tipping to a 20 to 30 degree angle with a relatively simple dumper or hoist and allowing the apples to flow out through the door onto a conveyor.

Three systems were in use for lowering the box into the water in the water flotation system: hydraulic or pneumatic cylinder operation, mechanical operation, and submarine type operation. Hydraulic or pneumatic cylinders were ideal to supply the necessary force to submerge and remove the box and carriage from the water. The platform for the bulk box was connected directly to four chains and moved downward and upward with their travel. The submarine system used an open inverted tank into which air was pumped to displace the water to provide the force for lifting the carriage out of the water. The carriage had sufficient weight to submerge the box (Pflug and Levin, 1961).

Pflug and Dewey (1960) described the principles of operation and important design features of a machine for unloading bulk boxes of apples by water flotation. The system utilized the fact that apples are less dense than water. A pneumatically operated carriage lowered the box vertically in the tank. A wood roller conveyor removed the fruit from the water and delivered it to the dryer and packing lines.

Stout et al (1962) used a bulk box with a split-pallet with removable cardboard sides. Dumping was accomplished with a forklift which had hydraulically operated hinged forks that opened the pallet. Tomatoes were dumped into a tank of water. Observations indicated that the operation was simple and did not cause injury to the fruit.

Burt (1961) described a mechanical dumper used to dump applies. Field crates were fed into it by a friction drive conveyor which could maintain a reservoir of 30 or more crates. The crates were dumped by a rotating drum. Except for refilling of the friction drive conveyor, the dumping operation was automatic.

According to Dreyer (1962), there is a commercial lug box pallet unloader and lug dumper in operation to unload tomato crates in California. The crates are unloaded from the pallet by a clamp and then dumped for a mechanical dumper.

Pearl (1963) stated that 16,000 tons of California's processing tomatoes were mechanically harvested. Tomato bulk handling may become widespread even with hand harvest. It was reported at the National Canners Association meeting that 17,000 tons of tomatoes were hand harvested into bulk boxes in 1962 in California (Stout, 1963).

This review of literature indicated that considerable progress has been made to develop a mechanical tomato harvester. Many fruit handling operations have been mechanized. Studies on bulk box handling indicated that a continuous flow dumper mechanism to provide a high handling capacity was needed to keep up with the new developments on tomato handling.

DESCRIPTION AND OPERATION OF THE MSU BULK BOX DUMPER

The MSU bulk box dumper wasa high capacity, continuous flow, partial submersion system. The dumper consisted of a box receiver connected to a full box conveyor by a short section of roller conveyor, the dumper mechanism, the empty box conveyor, the empty box roller conveyor, and the necessary hydraulic and water circulation system (Figures 1, 9, and 11).

Tomatoes were dumped into a tank of water 4-1/2 feet wide and 4 feet deep. The water was recirculated by two pumps having a total capacity of about 550 gpm to produce a current to carry the tomatoes from the tank through a flume to an elevator.

The system was filled with water from a nearby irrigation well. Steel mesh or wooden bulk boxes filled with tomatoes were brought from the harvester and placed on the box receiver, previously raised by a hydraulic cylinder. After the forklift arms were removed the box receiver lowered the box onto a horizontal section of roller conveyor which served as a holding area (Figure 2).

The box was pushed manually over the rollers to the full box conveyor (Figures 3, 9, and 10). This conveyor consisted of three pressed steel chains, each supported by a wooden beam. An electric motor powered the conveyor to

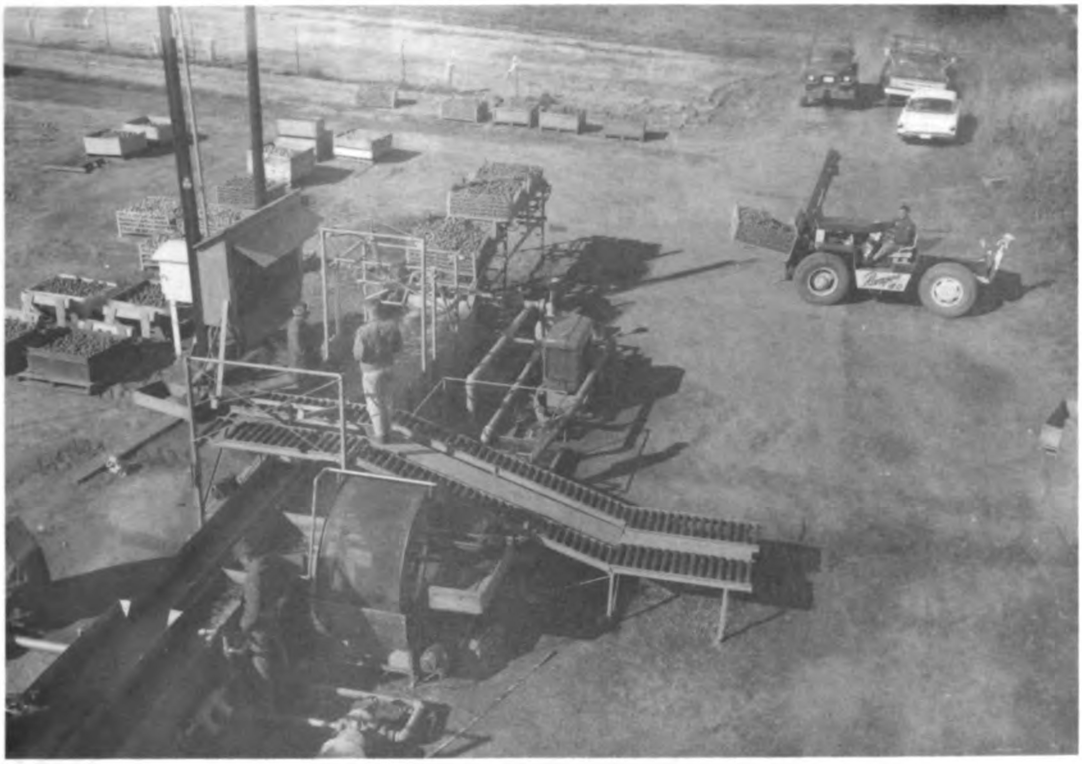

Figure 1. Overall view of the bulk box dumper.

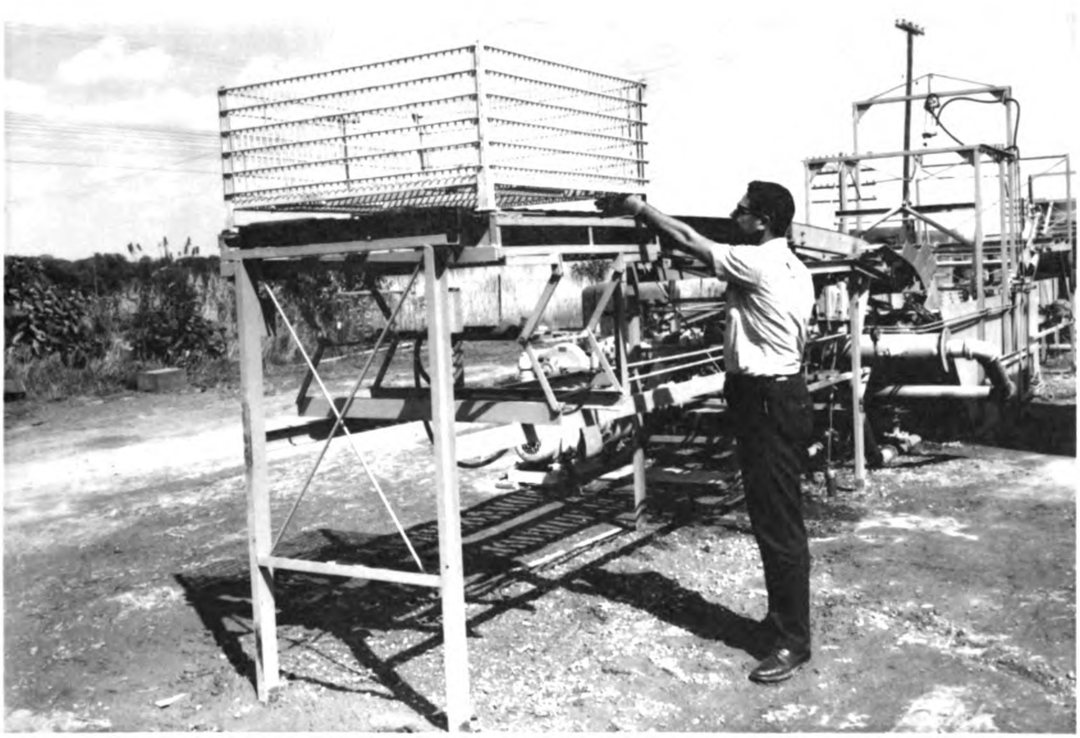

Figure 2. Box placed on the roller conveyor.

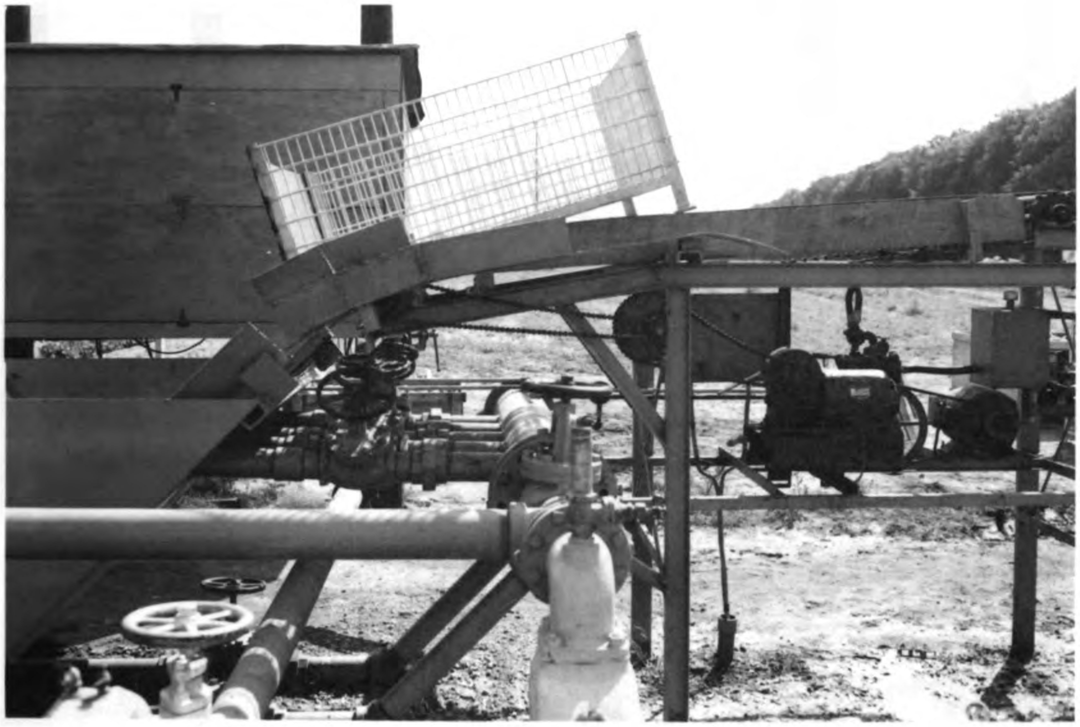

Figure 3. Side view of full box conveyor.

Figure 4. Box sliding into the dumper mechanism.

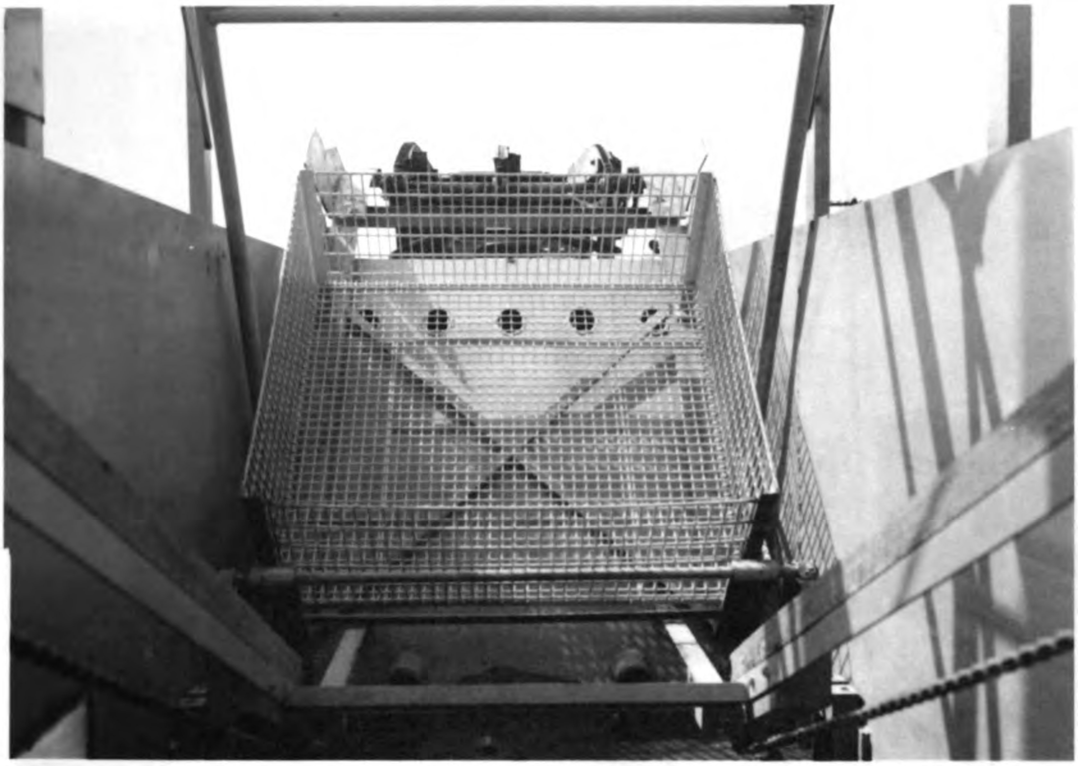

Figure 5. Box placed on the dumper mechanism.

Figure 6. Inverted box being removed from tank by empty box conveyor.

Figure 7. The box being transferred to the roller conveyor.

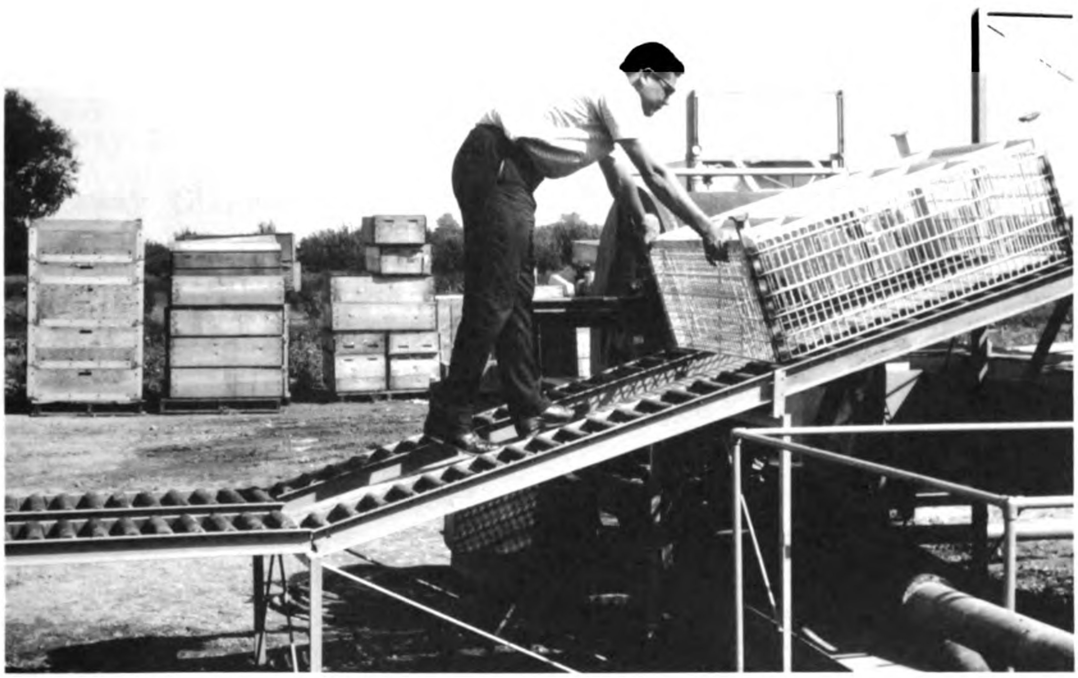

Figure 8. The box being taken away on the empty box roller conveyor.

move the box to the dumper tank at a velocity of about 40 fpm.

The full box conveyor was curved to a suitable angle in order to slide the box smoothly into the dumper tank, avoiding a high impact force which could damage the boxes and splash too much water. The boxes were cushioned by water as they slid into the dumper mechanism, which was inclined at a 45 degree angle, and were about two-thirds submerged when they came to rest (Figures 4 and 5).

The dumper mechanism consisted of a platform to hold the box, a hydraulic cylinder, and a lifting linkage (Figures 11 and 12). The box was rotated about 70 degrees by the hydraulically operated dumper causing it to overturn onto the empty box conveyor (Figure 6). It was then carried up a 30 degree slope gently discharging the fruit while gradually being removed from the water (Figure 7). Then the empty boxes were transferred from the empty box conveyor to the empty box roller conveyor which permitted them to be taken away (Figure 8).

The hydraulic system (Figure 13) consisted of a hydraulic pump, three double acting 8-inch hydraulic cylinders 2-1/2 inches in diameter, three 3-position open center control valves, and an electric motor.

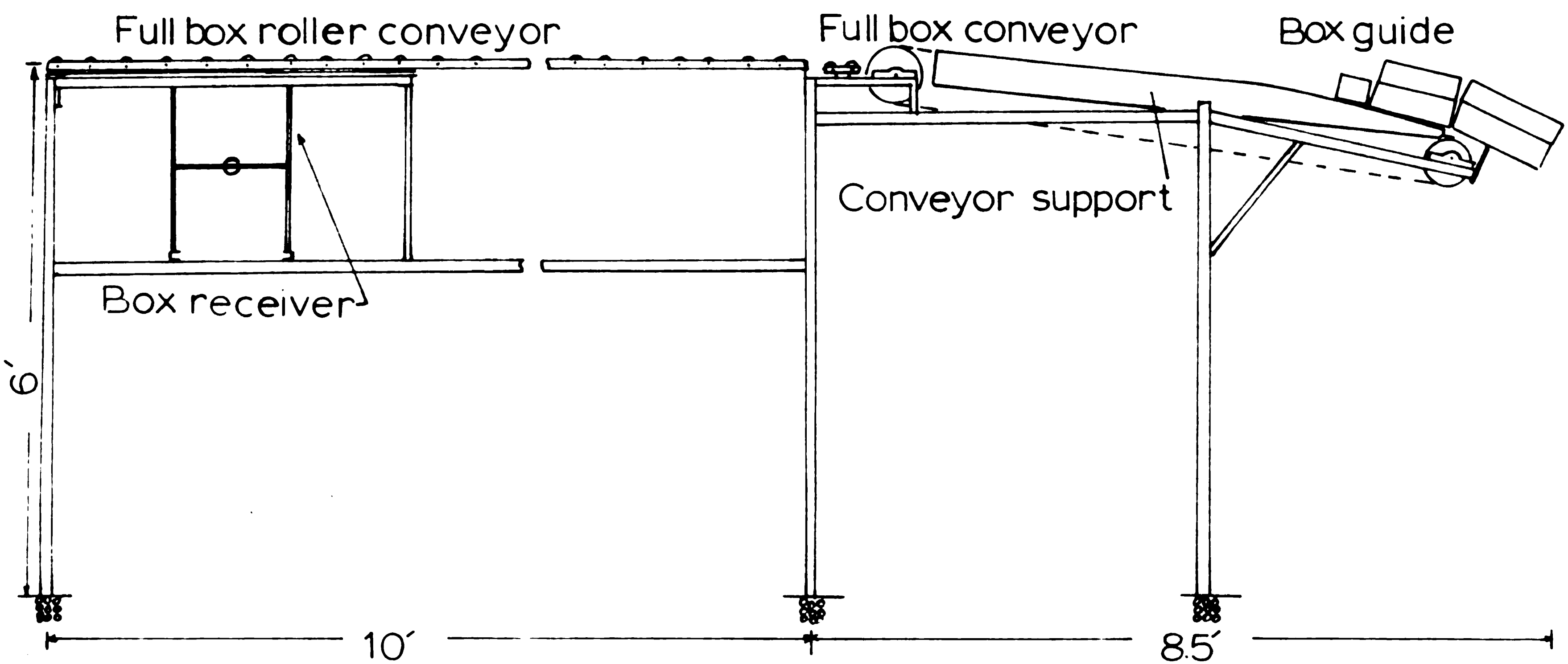

Figure 9. Side view of full box roller conveyor and full box conveyor.

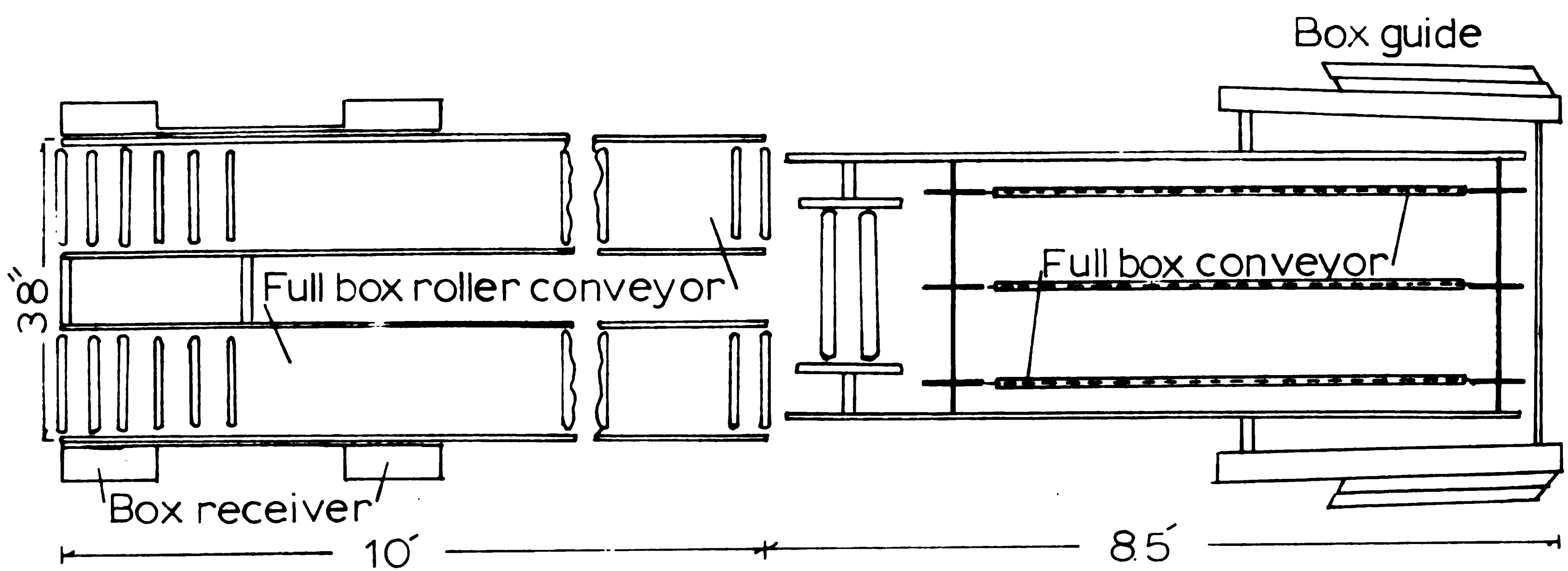

Figure 10. Top view of full box roller conveyor and full box conveyor.

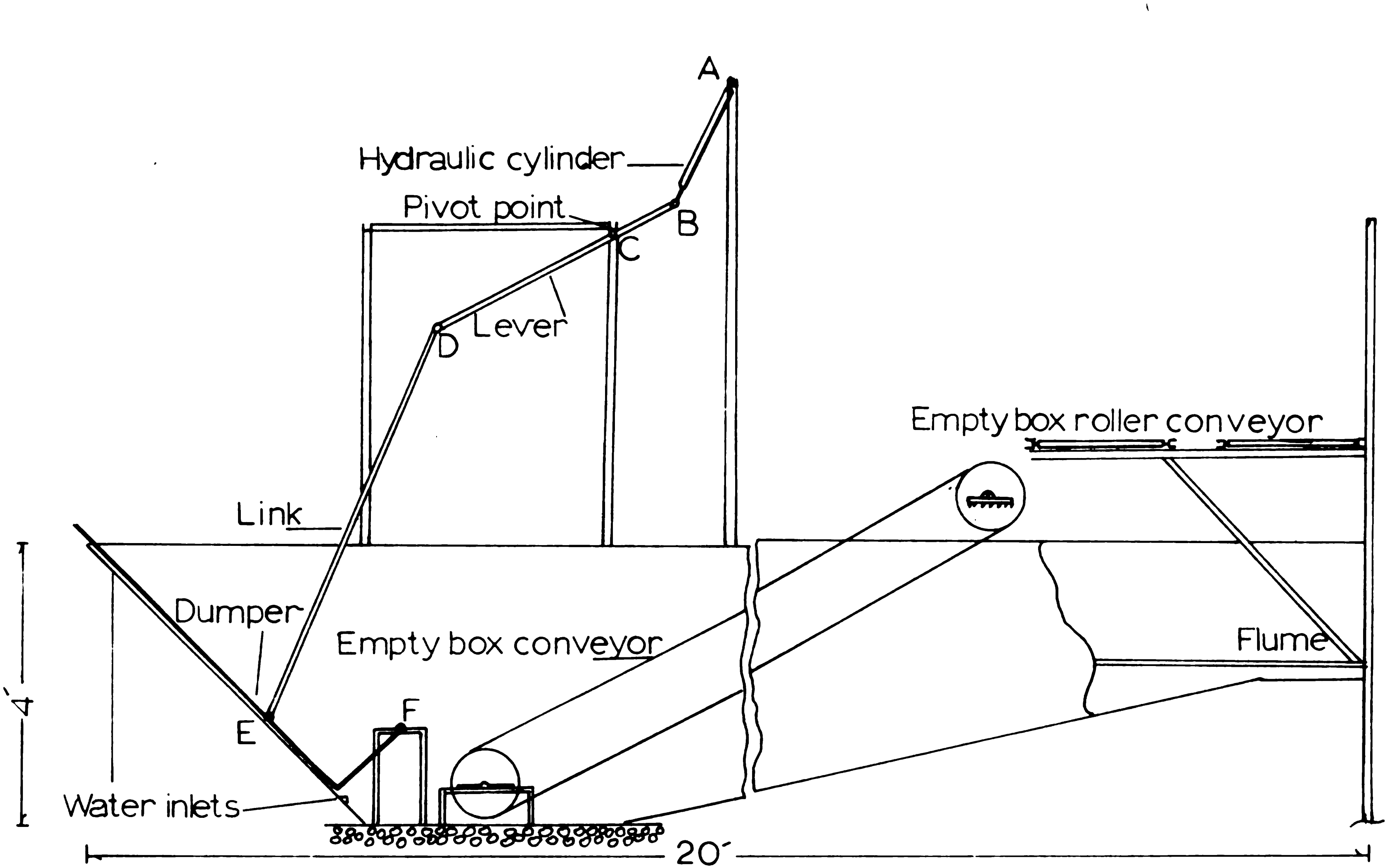

Figure 11. Side view of dumper mechanism, empty box conveyor, dumping tank, and flume.

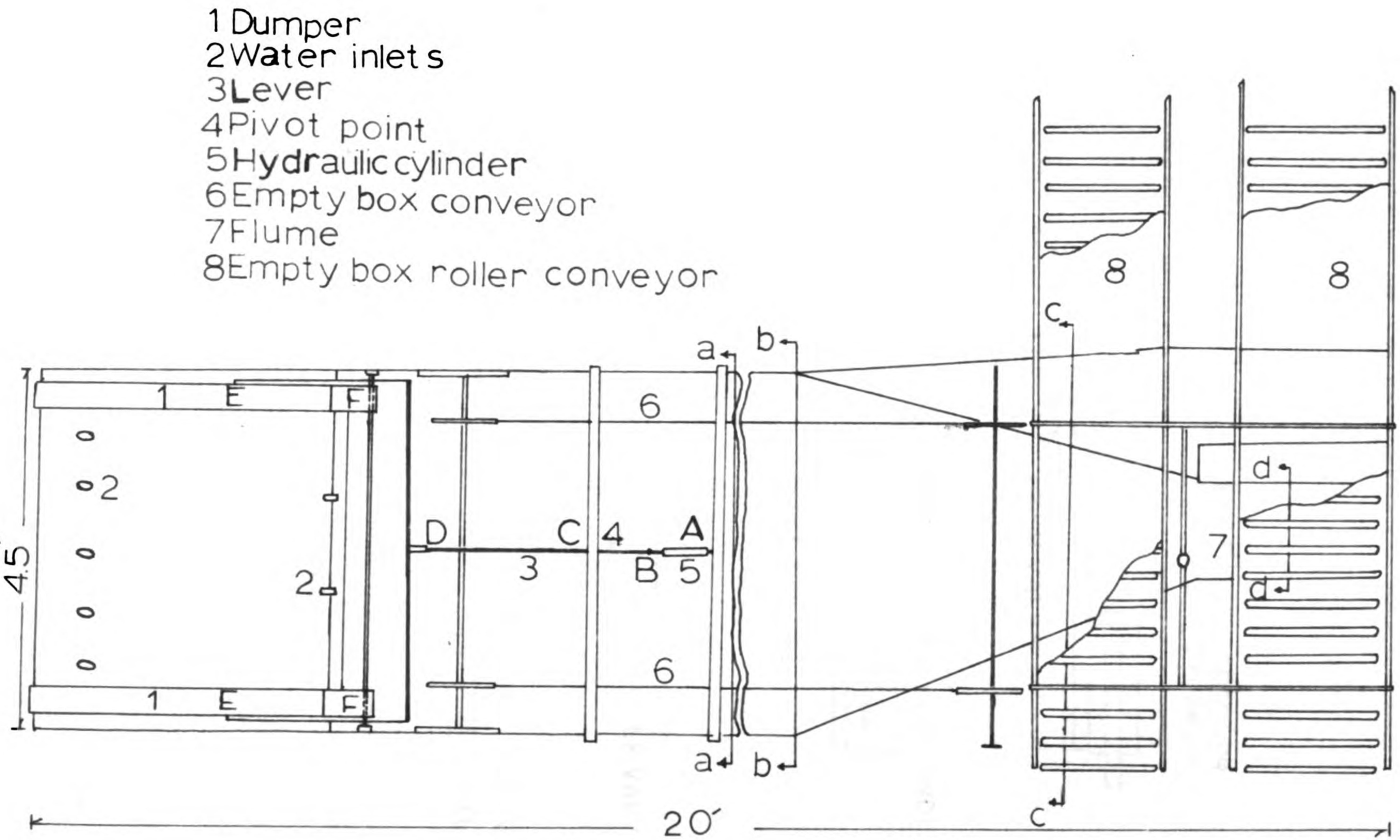

Figure 12. **Top view of dumper mechanism, empty box conveyor, dumping tank, and roller conveyor.**

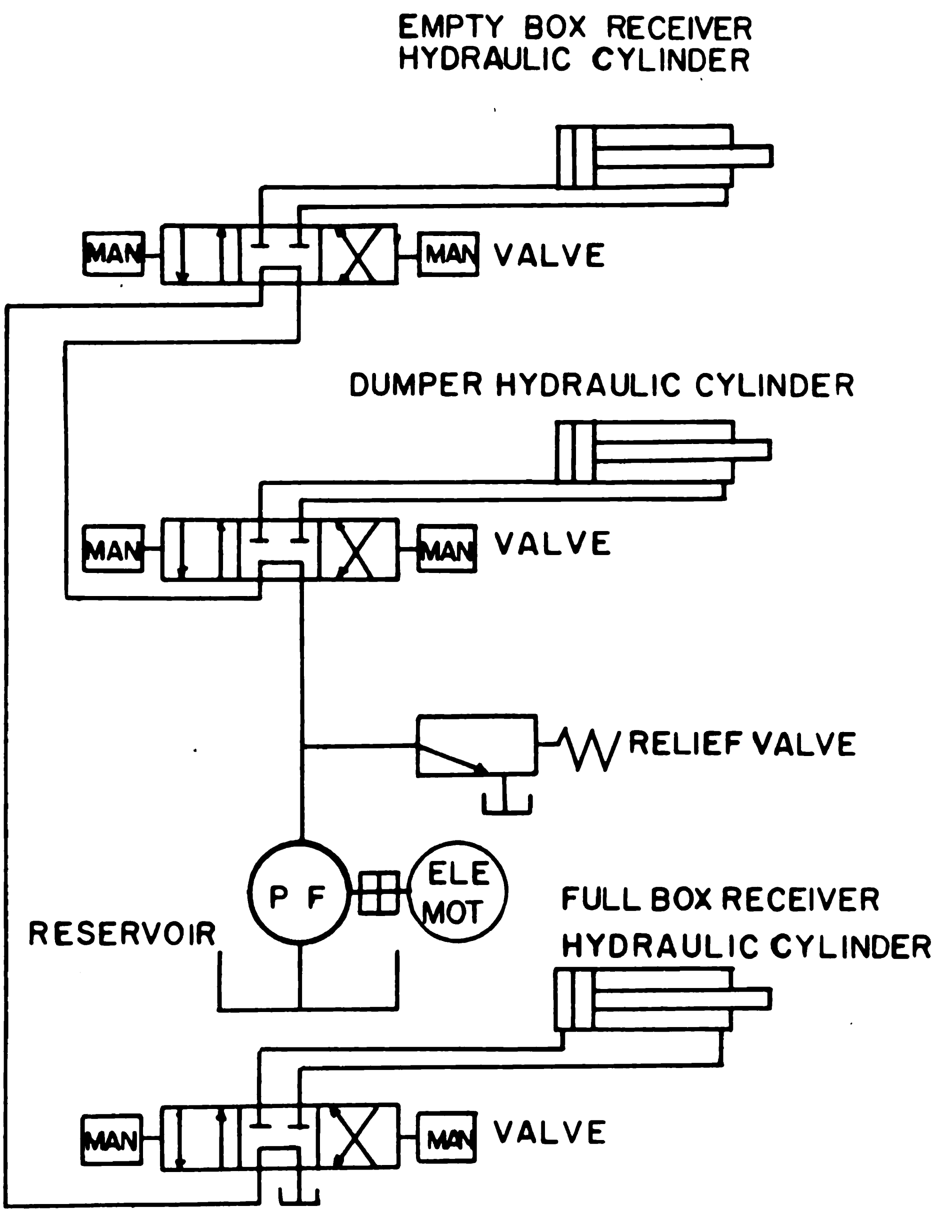

Figure 13. Schematic representation of the hydraulic system.

EVALUATION OF THE BULK BOX DUMPER

To evaluate the bulk box dumper three different types of tests were run. The tests consisted of the following:

1. Dumping capacity
2. Water velocity
3. Tomato quality

Dumping Capacity

Three kinds of tests were performed to evaluate the machine in terms of the number of boxes per hour or tons of tomatoes per hour dumped.

A. The first test consisted of dumping full boxes of tomatoes as fast as possible. Several full boxes of tomatoes were placed on the full box roller conveyor feeding the boxes to the dumping system. This was done to eliminate the possibility of having the dumper wait for a supply of boxes. Thus, the limiting factors of this capacity test were the dumper and the tomato handling facilities from there on.

B. The objective of the second test was to have as many boxes as possible going through the complete dumping cycle to evaluate the box handling capacity of the machine. The boxes were empty to eliminate the tomato handling system beyond the dumper as a limiting factor. The lift truck picked the boxes up near the empty box roller conveyor and placed them on the box receiver, thus the same boxes were passed through the process many times.

C. The third test was similar to the second but the boxes were placed on the full box roller conveyor by hand to eliminate the lift truck as a limiting factor.

Water Velocity

Preliminary dumping tests showed that the water circulation was irregular in the dumping tank. As a result, many ripe tomatoes accumulated on the bottom of the tank. The objectives of the water velocity test were to study the nature of the water currents in the tank and try to find the most suitable setting of the water inlet valves to produce a uniform water flow through a section of the tank. This would avoid the accumulation of tomatoes at the bottom.

A combined or differential pitot tube was used to obtain the water velocity at different points in the section (aa) of the dumping tank.

Henderson and Perry (1955) described a differential pitot tube. The static and total pressure elements were combined in one tube. The static orifice consisted of a ring of small holes drilled in a circumferential sleeve surrounding the impact orifice.

The water velocity was calculated using the Bernoulli theorem:

$$V = C \sqrt{2gh}$$

where
- V = velocity, feet per second
- H = head, feet of water
- g = acceleration due to gravity, feet per sec^2
- C = velocity coefficient

According to Eckman (1958), the velocity coefficient equals one for this pitot tube having a long impact-opening extension. The differential pressure, H, was read on a glass manometer scaled in inches. Figure 11 shows the location of the section (aa) where differential pressures were measured.

Three different kinds of tests were made. Only four of the seven water inlets were used; two located in the upper part of the tank head and two in the bottom (Figure 11):

A. The four water inlet valves were opened during the first test. The valves were opened with five turns of the handle.

B. The second test was conducted having the upper inlet valves 2-1/2 turns opened and the bottom opened.

C. In the third test, the upper water inlet valves were opened and the bottom 2-1/2 turns opened.

Tomato Quality

Four southern grown tomato varieties, Campbell 1327, Libby 6-52, Heinz 1350, and Heinz 1370, were used to study the fruit quality after they passed the handling process.

By handling the tomatoes in different bulk boxes it was possible to evaluate the box type and the resultant fruit quality after they were taken through the entire handling system. The weight of the boxes when empty or filled with tomatoes is given in Table 2. There were at least two replications harvested for each box size or type and each treatment discussed in the tables.

Mechanically harvested tomatoes were placed in the bulk boxes. The boxes were transferred by forklift to a tractor drawn trailer or a truck and delivered to the dumping and washing apparatus.

Samples of 50 fruit each were taken from the top four and bottom four inches of each bulk box. The number of fruits having cracks over one inch and the number of crushed fruits were recorded. A fruit which had lost approximately 50 percent of its total volume was considered crushed.

On the following day the fruits were dumped, flumed, and washed. A time interval was allowed between dumping each box so that there would be an observable gap in the flow of tomatoes across the sorting table. The number of crushed fruits were determined by taking 100-fruit samples at random from the sorting table.

On two occasions samples of cracked and non-cracked fruits were selected from hand- and machine-harvested lots. The variety Heinz 1350 was hand- and machine-harvested into 40-pound lug boxes (replicated six times), 50-fruit samples were taken prior to dumping. These lots were dumped near the washer so that they would not be separated in the washing process. One hundred fruit samples were taken from the sorting table for these tests. Cracked or crushed fruits were counted before and after dumping. Comparing the results of these tests dumped by hand with the results of the tests dumped by the dumper, an idea of the effect of the dumper on the tomato quality could be drawn.

RESULTS AND DISCUSSION

The theoretical dumping capacity was approximately the same when full and empty boxes were handled by the forklift. From the data on Table 1 an average dumping capacity of 123 boxes per hour may be calculated. Table 2 shows that the average weight of tomatoes held by steel mesh boxes was 830 pounds. This would yield a dumping capacity of over 50 tons of tomatoes per hour.

Table 1 also indicates a theoretical dumping capacity of 145 boxes per hour when the empty boxes were placed by hand on the roller conveyor. However, it must be noted that the speed of this operation was faster than that performed with the forklift, because it was easier for the workers to pick up the empty boxes and place them on the roller conveyor.

The washing and the water circulation systems were limiting factors for the dumping capacity. It was observed that the washing system capacity was insufficient to take all the tomatoes out when full boxes were dumped during the speed dumping test. Many tomatoes were accumulated in the flume and in the tank next to the flume. The amount of tomatoes carried out by the washing system elevator exceeded its capacity, this caused the tomatoes to fall off the elevator.

The water circulation system did not provide an even flow of water in the dumping tank, causing an accumulation of ripe tomatoes on the bottom of the tank.

The results of the water velocity test are presented in Figures 14, 15, and 16. These figures also show the locations of the water inlets relative to the section in which the measurements were made.

Figure 14 shows that the water flow was uneven in that section. There were currents in opposite directions to the desired flow, as indicated by the negative signs of some of the velocities measured, as well as some points where there was no velocity at all. This phenomena also is noticed in Figures 15 and 16.

When the water inlets A and B were opened and C and D opened 2-1/2 turns, the flow was approximately even at the top of the section, but as can be seen from Figure 16, the flow at the bottom of the section was in opposite direction.

Figure 16 indicates that the water inlets A and B were opened 2-1/2 turns and C and D were opened. The water current was in the desired direction at the bottom of the section and in the inverse direction at the top of the section.

These three tests demonstrated the difficulty of obtaining an even flow of water across the section (aa) of the dumping tank. The even flow of water is necessary to transport all the tomatoes from the dumping tank to the flume and washing system without having them deposited in the dumping tank. The uneven flow could be due to the irregular shape of the tank and the position of the water inlets.

An attempt to measure velocity of water in other sections (bb, cc, in Figure 12) were made, but the observations demonstrated that the water flow was more irregular in those sections.

An average velocity in the section (aa) of about 0.11 fps was calculated. From these data the water flow was computed as follows:

$$Q = V \times A = 0.11 \times 60 \times 7.48 \times 4.5' \times 2.5' = 550 \text{ gpm}$$

Where:

Q = flow in gallons per minute
V = velocity in feet per second
A = area of section aa = 2.5×4.5 ft^2

The average velocity as measured in the flume, the area of which was 0.667 square feet, was 1.85 fps. The calculated water flow was:

$$Q = 1.85 \times 60 \times 7.48 \times 0.667 = 550 \text{ gpm}$$

The results of the tomato quality test are presented in Tables 3 and 4.

Table 3 shows damage to tomatoes handled in four bulk box types as percentage of fruit cracked before dumping and percentage of fruit crushed after washing. An average of 30 percent of the machine harvested tomatoes were cracked before dumping; whereas, an average of 17.4 percent of the hand-harvested tomatoes were cracked. According to this, approximately twice as much fruit was damaged by machine as by hand harvesting. About six times more machine harvested tomatoes were crushed after washing as compared to the hand harvested tomatoes. From the crushed tomato results shown in Table 3, it can be concluded that the dumper mechanism caused little or no damage to the tomatoes.

Table 4 indicates a comparison of the hand and machine harvested tomatoes which were placed into lug boxes and then dumped by hand. It is noticed that about five times more machine harvested tomatoes were crushed than hand harvested tomatoes. The percentages of cracked fruit before dumping were similar to those presented in Table 3. However, if the crushed tomatoes percentages shown in this table were compared to those in Table 3, it could be observed that about twice as much fruit was damaged when the boxes were dumped by hand.

The results mentioned above indicate that the mechanical harvester and the washing system were responsible for most of the fruit damage and that the dumper mechanism did not cause an appreciable injury to the tomatoes.

From the observations of the performance of the dumper machine during its use in the entire 1962 harvest season can be suggested that for commercial adaptation the full box roller conveyor should be mechanized. The dumping operation should be synchronized with the full box conveyor that feeds the boxes to it. A suitable dumping tank shape to provide an even flow of water should be developed and the empty box roller conveyor should be mechanized.

Table 1. Time required to handle empty and full steel mesh boxes[1] with the MSU box dumper.

Boxes	Handled by	Ave. No. of Boxes	Ave. Time, Min.	Theoretical Dumping Capacity Boxes/hour
Empty	Forklift	18.5	9.1	122
Full	Forklift	26.0	2.9	124
Empty	Hand	22.0	9.1	145

[1] 15" x 47" x 47".

Table 2. A weight comparison of steel mesh and plywood bulk boxes 16 x 47 x 47 inches with built-in pallets.

Material	Average Weight, Pounds		
	Empty Box	Box + Tomatoes	Tomatoes
Steel Mesh	90	920	830
Plywood, Dry	100	880	780
Wet	130	--	--

Table 3. Damage to tomatoes handled in four bulk box types.*

Treatment	Variety Harvest	1350 1370 9/16	C-52 9/10	1327 9/12	1350 9/13	1370 9/19	1350 9/24	Av.
Fruit Cracked Before Dumping, Percent								
Hand Harvest Wood (16 x 22 x 42")		16.0	17.0	29.0	18.0	10.7	14.0	17.4
Machine Harvest Plywood (16 x 47 x 47")		41.5	19.0	39.5	31.0	27.3	30.7	31.5
Steel mesh (1 x 1" galvanized)		37.0	30.0	43.0	20.0	29.0	26.0	30.9
Steel mesh (1 x 1" plastic coat)		--	--	--	--	28.7	24.7	28.7
Machine harvest, av.								30.0

Treat-ment	Variety Harvest	1350 1370 9/16	C-52 9/10	1327 9/12	1327 9/13	1350 9/13	1370 9/19	1350 9/24	Av.
Fruit Crushed After Washing, Percent									
Hand Harvest Wood (16 x 22 x 42")		0.5	0.5	4.0	1.5	1.0	1.0	2.3	1.5
Machine Harvest Plywood (16x47x47")		5.0	10.0	12.0	9.0	4.5	5.3	11.7	8.2
Steel mesh (1 x 1" galvan-ized)		7.0	11.5	11.5	--	10.5	7.0	8.3	9.3
Steel mesh (1 x 1" plastic coat)		--	--	--	11.0	--	8.0	8.3	9.1
Machine Harvest, Ave.									8.8

*These boxes were dumped with the Michigan State University dumper.

Table 4. A comparison of hand and machine harvest into lug boxes with Heinz 1350 and dumped by hand.

	Injury, Percent	
Harvest	Cracked Before Dumping	Crushed After Washing
Hand	19.3	3.3
Machine	30.0	16.7

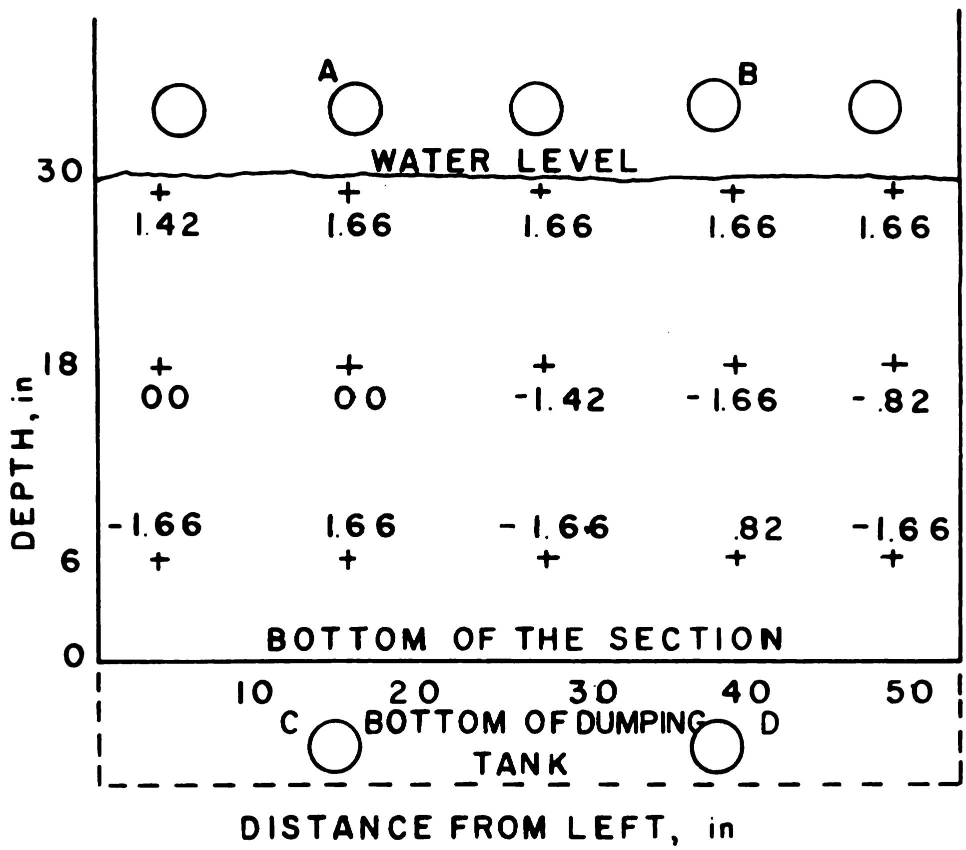

Figure 14. Velocity profile, fps, in section (aa). Water inlets A, B, C, and D opened.

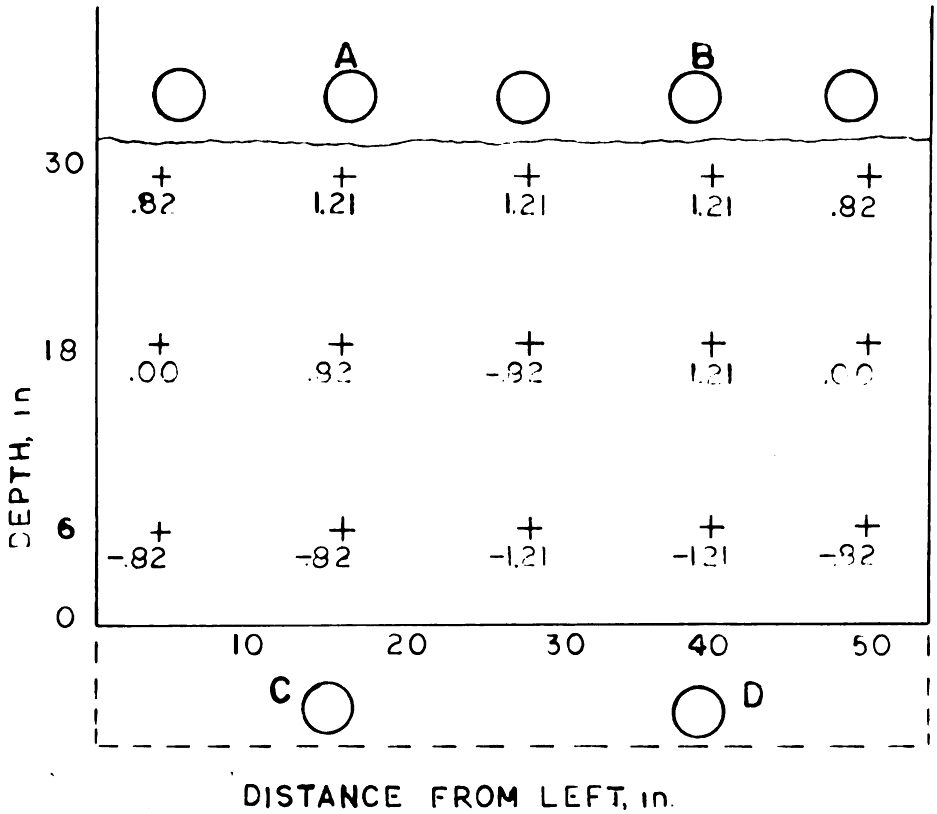

Figure 15. Velocity profile, fps, in section (aa). Water inlets A and B opened. Water inlets C and D 2-1/2 turns open.

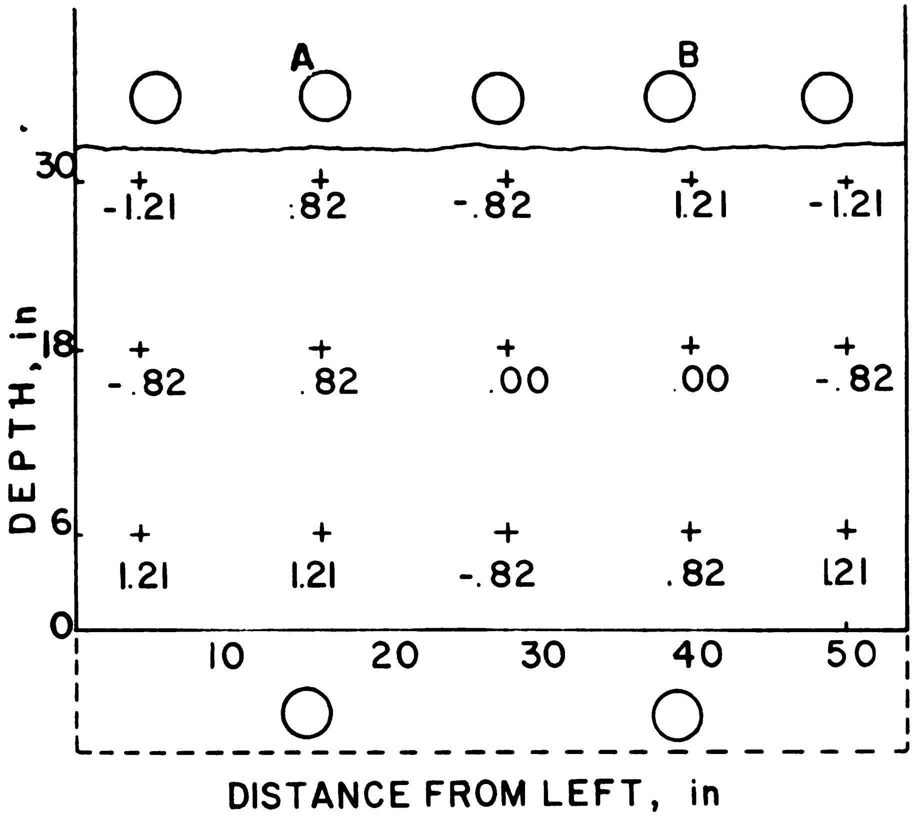

Figure 16. Velocity profile, fps, in section (aa).
Water inlets A and B 2-1/2 turns opened.
Water inlets C and D opened.

CONCLUSIONS

1. The Michigan State University dumper had a theoretical dumping capacity of about fifty tons per hour, which met the requirements specified by commercial tomato processors.

2. The dumper mechanism caused no appreciable injury to the tomatoes.

REFERENCES

Anonymous. 1961. Mechanical harvesting and handling in the United States. International Fruit World No. 1:334-349. Spring.

Dreyer, J. A. 1962. Written communication, October 29.

Eckman, D. P. 1958. Industrial Instrumentation. New York: John Wiley and Son, Inc., 396 pp.

Fairbanks, B. 1958. Machine-picking tomatoes. Farm Management, 7 (1):34-36.

Gaston, H. P. and J. H. Levin. 1959. Handling apples in bulk boxes. Mich. Agr. Expt. Sta. Special Bul. 409. 20 pp.

Grierson, W. 1962. Handling Florida oranges in pallet boxes. U. S. Department of Agriculture. Marketing Research Report No. 529. 59 pp.

Hedden, S. L., J. H. Levin, and H. P. Gaston. 1960. A progress report on harvesting and handling Concord grapes. U. S. Department of Agriculture. Washington, D. C., ARS 42-42. 15 pp.

Herrick, J. F., Jr., S. W. McBirney, and E. W. Carlsen. 1958. Handling and storage in pallet boxes. U. S. Department of Agriculture. Washington, D. C. AMS 236. 41 pp.

Henderson, S. M. and R. L. Perry. 1955. Agricultural Process Engineering. New York: John Wiley and Son, Inc. 402 pp.

Levin, J. H. and H. P. Gaston. 1957. A bulk box dumper. Mich. Agr. Expt. Sta. Quart. Bul. 39 (4):557-562.

________. 1958. Equipment used by deciduous fruit growers in handling bulk boxes. U. S. Department of Agriculture. Washington, D. C. ARS 42-20. 11 pp.

McBirney, S. W. 1959. New developments in fruit harvesting and handling in the Pacific Northwest. Ithaca, New York. ASAE Paper No. 59-139. June.

McBirney, S. W. and A. Van Doren. 1959. Pallet bins for harvesting and handling apples. Washington Agr. Expt. Sta. College Sta. Stations Circ. 355. 11 pp.

Murphy, D. H. 1960. Tomatoes are picked by experimental machine. Canner Packer. 129 (1):40-41.

O'Brien, M. 1960. Design for bulk fruit boxes. California Agr. Expt. Sta. Cir. 490. 11 pp.

Pflug, I. J. and J. H. Deway. 1960. Unloading soft-fleshed fruit from bulk boxes. Mich. Agr. Expt. Sta. Quart. Bul. 43 (1):132-141.

Pflug, I. J. and J. H. Levin. 1961. Water flotation bulk box unloader for fruits. Eastern Fruit Grower. 24 (6):6, 14, 16-17.

Pearl, R. C. 1963. Tomato mechanical harvest research in California. National Canners Assn. Information Letter No. 1909. Washington, D. C., January 31.

Ries, S. K., B. A. Stout, C. L. Bedford, and M. E. Austin. 1961. Mechanical harvesting and bulk handling test with processing tomatoes. Mich. Agr. Expt. Sta. Quart. Bul. 44 (2):282-300.

Stanley, W. B. 1961. Apple handling and packing in the Appalachian area. U. S. Department of Agriculture. Washington, D. C., Marketing Research Report No. 476.

Stout, B. A., S. K, Ries, M. E. Austin, A. Diaz, and E. Gonzalez. 1962. A summary of 1962 mechanical tomato harvesting and handling research. Michigan State University Report. 39 pp.

Stout, B. A. 1963. Oral communication. February 4.

Twigg, B. A. 1961. Water handling of tomatoes. National Canners Assn. Information Letter No. 1813. Washington, D. C., January 31.

U. S. Department of Agriculture. 1962. Vegetables-Processing. Annual summary. Acreage, production, and value of principal commercial crops. Statistical Reporting Service, Washington, D. C.

Zahara, M., J. H. MacGilligray, and L. J. Clemente. 1959. Forklift loading of canning tomatoes. University of California. Davis, California. Series 96. 12 pp.